ENCLOSURE A
COMMENTS ON STORMWATER LOADING CALCULATION METHOD

Document Section	Editorial/Technical Comment	EPA Comment
Global	Editorial	Throughout document there are references to “first round” and “second round” of data. In future documents, all references to “first round” should be changed to “Round 3A” and “second round” to “Round 3B”.
Global	Editorial	There needs to be a discussion of assumptions used in this assessment (e.g., there is no correlation between activities conducted within a land use and stormwater loading).
Global	Editorial	In the future, there needs to be a discussion of the uncertainty in this analysis.
1.0, p.1	Editorial	In future documents, all data used for the study should be noted. Section 1.0 of this document only discusses Round 3A data. It is not until Section 3.0 that the Port of Portland’s data is discusses, and Section 4.0 that the GE data is discussed.
2.0, p.3	Editorial	The objective of the loading evaluation is to provide data to ***understand the fate and transport of upland stormwater discharges to the Willamette River***.
2.1, p.3 First Bullet	Editorial	Understand ***relative*** stormwater…
2.1.2, p.4 pp. 1, sent. 1	Editorial	Stormwater ***solids*** discharges …
2.1.2, p.4 pp. 2, sent. 1	Editorial	…estimates of stormwater ***solids*** loads…
2.2, p.5 pp. 2 (after bullets), sent. 2	Editorial	…estimating these ***model input*** loads…
2.2, p.5	Editorial	It is unclear how stormwater loads will be used to help set sediment PRGs. Please elaborate.
3.2, p.7 last pp, sent. 1	Editorial	…compounds that are ***suspected*** to be a risk driver…
3.3, p.7	Editorial	This discussion is very confusing as written. For future documents, chemical lists should be limited to actual lists of chemical determined to be needed for each of four bullets with rational or citation to rational.

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4.0, p.9	Editorial	EPA does not agree that direct measurement of all outfalls would require an unreasonably large number of measurements or that there are practical constraints (other than time and resources). The purpose for using representative land-use samples in lieu of sampling every stormwater outfall was to determine generalized pollutant values for land uses. Because this data is being used to determine reasonable estimates of stormwater loads on aggregate to the whole site, rather than individual loads for purposes of source identification and control, it was determined that a reasonable subset of the total storm water outfalls could be sampled to represent various land uses and extrapolated to the whole site.
4.1, p.9	Editorial	In future documents, reference that the GE sample collected was similar methodology to the FSP.
4.1, p.9 1st bullet	Editorial	…within the overall drainage area ***to the Site***.
4.1, p.10 3rd subbullet	Editorial/Technical	Heavy industrial (***20*** locations***, includes non-unique data from 15 unique locations***) ***representing X percent of the overall drainage to the Site.*** Need to provide X in future reports.
4.1, p.10 4th subbullet	Editorial	Light industrial (five locations) ***representing X percent of the overall drainage to the Site.*** Need to provide X in future reports.
4.1, p.10 1st bullet	Editorial	…sources that ***were determined not to be representative of*** generalized land use measurements. ***The initial list of chemicals to be evaluated as unique for each of these sites is presented in Table X.***
4.1, p.10 1st bullet	Editorial	Future documents should discuss St. Johns bridge and Schnitzer samples from Round 3A, as appropriate.
4.2.1, p.11 last sent.	Editorial	In this case, the ***data*** may be converted to…
4.2.2, p.11 pp.1	Editorial	It should be stated up front that for this analysis all unique industrial sites are heavy industrial land use.
4.2.2, p.11 pp.1, sent. 2	Editorial/Technical	In future documents reflect that loading rates for unique sites will be associated with drainage area for the entire property for that upland site.

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Document Section	Editorial/Technical Comment	EPA Comment
4.2.2, p. 11 pp.2	Editorial	This paragraph is confusing and it is unclear what the "data reduction approach" is. It is believed that this is an attempt to discuss the recategorization of unique and heavy industrial land-use data. This paragraph should be deleted and add following sentence to end of first paragraph: ***Recategorization of unique and heavy industrial land-use data is discussed further in Section 5.3.***
4.2.3, p.12	Editorial	In future documents indicate that this is discussed further in Section 7.1 (or equivalent section).
4.3, p.12	Editorial	Estimation of long-term loads does not only involve water samples, but sediment trap samples as well.
4.3, p.12 pp.1, sent. 2	Editorial	…meet the objectives for the ***RI/FS because the intent is only to determine generalized pollutant values for land uses rather than to identify actual sources or conduct source tracing.***
4.3, p.12 pp.1, last sent.	Technical	It is inappropriate to compare whole water loads and solids loads because the partitioning of chemicals between these media will result in vastly differing loading rates. Whole water loads should be used primarily for relative risk contributions and solids loads should be used primarily for risk to benthic organisms and recontamination purposes. Solids loads should be calculated from both the whole water data and the in-line sediment trap data and compared to determine the uncertainty of solids loads to the site. Whole water solids loads can be calculated either using literature values for Kp term or best possible estimates available from limited LWG/Port data on filtered/unfiltered data pairs.
4.3, p.12 last pp.	Editorial	In future documents, please elaborate on the tools that are commonly applied to watersheds in the absence of detailed stormwater chemical data and how they will be used to evaluate future changes in source control and land use at this Site.
4.3.1, p.13	Editorial	It should be clarified in future documents that this is the method that is used for calculating water loading from whole water samples for the purpose of determining relative risk exposures in the water column.

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Document Section	Editorial/Technical Comment	EPA Comment
4.3.1.1, p.13	Editorial	Runoff volumes will be calculated ***for each river model cell (Figure 4.2) adjacent to the uplands*** using the City of Portland Bureau of Environmental Service's GRID model. Additionally, runoff volumes will be calculated for each ***upland property*** listed in Table 4-1...
4.3.1.2, p.13	Editorial	**4.3.1.2 *Chemical Load*** ***Chemical water loads*** will be calculated by multiplying the ***measured*** chemical concentration… C_w = Measured concentration (µg/L) for land use or ***unique*** site V_{month} = Volume of discharge (L/month) from land use or ***unique*** site over a month
4.3.2, p. 13	Editorial	It should be clarified in future documents that this is the method that is used for calculating solids loading from sediment trap data for the purpose of determining relative risk exposures for benthic organisms and recontamination analysis.
4.3.2.1, p.13	Editorial	Runoff volumes will be calculated ***for each river model cell (Figure 4.2) adjacent to the uplands*** using the City of Portland Bureau of Environmental Service's GRID model. Additionally, runoff volumes will be calculated for each ***upland property*** listed in Table 4-1...
4.3.2.2, p.14	Editorial	…order to relate chemical concentrations (mass of chemical per mass of ***solids***) measured in ***in-line sediment traps*** to stormwater ***solids*** loading to the Site. Total organic carbon (TOC) concentrations ***measured in the stormwater solids*** will be used to normalize the ***stormwater solids*** chemical concentrations and determine loads on an organic carbon (instead of TSS) basis. ***This will be done by multiplying the TOC in stormwater solids by the stormwater solids chemical concentration.*** Both TOC-based…
4.3.2.2, p.14	Editorial	Need to explain in future documents the rational for looking at loading on an OC-normalized basis.

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Document Section	Editorial/Technical Comment	EPA Comment
4.3.2.3, p.14	Editorial	**4.3.2.3** ***Chemical Loading*** ***Chemical solids loads*** will be calculated by multiplying the ***measured stormwater solids*** chemical concentrations (mass of chemical per mass of ***solids***)by the TSS (mass of ***suspended solids*** per volume of … C_s = Measured concentration (µg/kg) for land use or ***unique*** site TSS = Total suspended ***solids*** (kg/L) in stormwater measured for land use or ***unique*** site V_{month} = Volume of discharge (L/month) from land use or ***unique*** site over a month
4.3.2, p.14	Editorial	Need discussion of calculating chemical loads from whole water samples using the following equation. $L_{S,W}=C_{S,W}*V$ $C_{S,W}=C_w*X_s$ $X_s=1 – [1/(1+Kp*TSS)]$ Kp(metals)=see above Kp(organics)=Koc*Xoc Koc= - 0.54 log Sw + 0.44 Xoc=1 – DOC/TOC $L_{S,W}$=Solids load from water data (ng/d) $C_{S,W}$=Concentration sorbate in solids (ng/L) X_s=Sorbed fraction Sw=water solubility of sorbate Xoc=mass fraction OC in solids C_w= Total whole water concentration (ng/L) V=Volume of discharge (L/month) from land use or unique site over a month
5.0, p.15	Editorial	In the future, need to include discussion of whole water-based solids loading.
5.0, p.15 step 3	Editorial	3. ***Recategorization of Data*** (Section 5.3) – ***This section provides the process*** to evaluate Unique and Representative Heavy Industrial ***data on a chemical-specific basis*** to identify ***which data*** could be reclassified from Unique to Representative or from Representative to Unique.
5.0, p.15 step 4	Editorial	…evaluated for the presence of outliers for each land use category…

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5.1, p.18 3rd line	Editorial	…be included ***in land use data sets*** as follows
5.1, p.18 1st bullet, last sent.	Editorial	***Otherwise,*** the St. John's Bridge data ***will*** be combined with the major transportation data.
5.1, p.18 2nd bullet	Editorial	In future documents need to discuss fate of this data.
5.1, p.18 pp.2	Editorial	Remove "…and explained further in Section 5.3.1.1." since there is no section in this document.
5.2, p.19	Editorial	Title should be "Handling of Duplicates and Replicates" since both are discussed in this section.
5.2, p.19 pp.2, sent. 1	Editorial	Need to define "relatively consistent".

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Document Section	Editorial/Technical Comment	EPA Comment
5.2, p.19 pp.2 5.2.1 & 5.2.2	Technical	For all future analyses, the process for evaluating field duplicates and lab replicates should be as follows: • Compute relative percent difference (RPD) for each normal/duplicate and normal/replicate data pair. Relative percent difference (RPD) is a measure of precision, calculated by: $RPD = [X1 - X2]/Xave \times 100$ where: $X1$ = concentration in normal sample; $X2$ = concentration in field duplicate or lab replicate; and $Xave$ = average concentration = $[(X1 + X2) / 2]$ If the RPD is greater than levels presented in Table 4.2 of the *Portland Harbor RI/FS Round 2 QAPP Round 3A Stormwater Sampling*, January 19, 2007, then the samples will be determined to undergo an outlier analysis as described in the next bullets. (Note: This step should not be performed for chemicals that do not have an RPD value presented in Table 4.2 of the *Portland Harbor RI/FS Round 2 QAPP Round 3A Stormwater Sampling*, January 19, 2007; a quantitative analysis should be performed using BPJ to determine if samples are thought to be divergent and the analysis should be presented in future documents). • For divergent samples, conduct further investigation with field and lab staff and notes to determine any reasons for divergence. Data pair or individual data point may be segregated from data set if a substantial reason (e.g., information that field or lab procedures likely impacted results) exists for divergence, depending on reason. This will require BPJ and a full discussion of rational shall be provided in any future documents. • If no substantial reason for divergence can be found, compare data pair to other data points in the corresponding land use category. If the data pair is found to be with the range of data for that land use, then average the duplicate or replicate results with the corresponding normal sample. If either data point in the data pair are outside the range of data points in the corresponding land use category, then segregate data pair from data set. Note: Segregated data may be used in uncertainty analysis and conclusions discussions.

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Document Section	Editorial/Technical Comment	EPA Comment
5.2, p.19 pp.2 5.2.1 & 5.2.2	Technical	In all future analyses, sediment trap duplicates shall be averaged due to the extremely limited data set. However, the analysis of divergent duplicates should still be conducted and the impact of those averaged data on the analysis should be evaluated and discussed.
5.3, p.21	Editorial	The objective of this section is to evaluate the data for each land use to confirm that the data appropriately represents the land use.
5.3.1, p.21 pp.1, sent.3	Editorial	…industrial sites were categorized as Unique ***for certain chemicals***, anticipating that ***this data*** would not be used in…
5.3.1, p.21 pp.2	Editorial	…quantitative and qualitative (***e.g.,*** graphical) methods to evaluate ***on a chemical-specific basis*** whether the unique ***and*** heavy industrial ***data sets*** contain outliers that could be reassigned ***(e.g., unique to heavy industrial or heavy industrial to unique)***.
5.3.1, p.21	Editorial	In all future documents, a discussion of the purpose for weighting the data set for each land use must be provided.

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Document Section	Editorial/Technical Comment	EPA Comment
5.3.1, p.21	Technical	For all future analyses, the process for evaluating land use data should be as follows: Method 1: Concentration loads • Enter data for land use into ProUCL 4.0, including ND. For data sets with NDs, ProUCL can create additional columns to store extrapolated values for NDs obtained using regression on order statistics (ROS). • Use ProUCL to conduct goodness-of-fit (GOF) tests to determine distribution of data. • Use ProUCL to conduct outlier tests. Outliers for heavy industrial land use will be recategorized as unique data if backed up by general information about the site activities and COI that would lead to such a conclusion. Outliers for other land uses will be retained in data set, but noted in conclusions discussion and uncertainty analysis. (This replaces discussion in Section 5.3.2) • Use ProUCL graphical displays to present histograms, Q-Q plots, and box plots. • Use ProUCL to present Summary Statistics and Estimates of Population Parameters for data set. Method 2: Weighted Loads • EPA recommends using the Gilbert (1987) and Manly (2001) approach based on stratified random sampling and handling of left-censored (nondetect) data (Helsel, 2005) as discussed in the attached Technical Memorandum (Attachment 1). Since the objective of this analysis is to obtain ranges of data for inputs to the Hybrid Model, EPA recommends computing an upper bound as described in attached powerpoint presentation (Attachment 2). Further, EPA recommends that a stochastic approach be used to determine model input parameters and has provided an example (Attachment 3).

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Document Section	Editorial/Technical Comment	EPA Comment
5.3.3, p.22	Technical	The objective of this section is to review data categorized as Unique site data (see Table X) to determine if it should be recategorized as Heavy Industrial land use for each chemical. The recategorization analysis will be conducted using the whole water data and supported with the sediment trap data. Whole water and solids stormwater data for each chemical will always be placed in the same category (i.e., heavy industrial land use or unique site). Due to the limited data set for pesticides, sediment trap data will govern any reclassifications for pesticides. For all future analyses, the process for evaluating recategorization of unique and heavy industrial data should be as follows: • Compare each unique site's data for each chemical to heavy industrial land use data for corresponding chemical. • If all data for a chemical at a unique site fall within the range of data for the heavy industrial land use, then recategorize data. If unique site data is outside the range of the heavy industrial land use data on either the high end or low end, or both, then the site remains unique. • Ensure that decision to recategorize data is backed up by general information about the site activities and COI that would lead to such a conclusion.
5.3.4, p.28	Technical	In the future, do not conduct reclassification evaluations in this section.
5.4, p.30	Technical	In the future, do not conduct the detailed outlier analysis in this section.
5.6, p.34	Technical	In the future, do not conduct the evaluation in this section since it is redundant with Section 5.3.1.
5.7, p.37	Technical	In the future, use ProUCL to present Summary Statistics and Estimates of Population Parameters for data set (see comment for Section 5.3.1).
6.1, p.41	Editorial	It should be noted in future documents that there is uncertainty in the TSS data that could be due to the various BMPs for solids control throughout the site.
6.1.1.2, p.42 pp.1	Technical	Remove last two sentences in this paragraph. It is inappropriate to determine data is an outlier using data collected outside of this analysis because the data was not collected for the same purposes, within the same location (i.e., within the Site), or using the same methodology. The process presented for Section 5.3.1 provides the appropriate methodology to use to determine outliers for TSS data. It is acceptable to compare TSS data collected from this project with TSS data collected outside this project as a discussion in the uncertainty section.

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Document Section	Editorial/Technical Comment	EPA Comment
6.2, p.42	Technical	The in-line solids data set for each land use is too small to determine outliers or distribution on a quantitative (or statistical) basis. A qualitative analysis for outliers may be conducted.
6.4, p.43	Technical	The TSS data measured in water and the TOC data measure in solids will be used to determine solids loading. Additionally, TOC in water should be used to calculate an OC normalized load.
6.4, p.43 pp.1, sent.1	Editorial	***Stormwater solids*** loading to the Site…
6.4, p.43 pp.1, sent.4	Editorial	…each case, the chemical concentrations in the sediment trap (either bulk ***solids*** or on…
6.4, p.43 pp.2	Technical	Delete last two sentences; there has not been enough study of these basins or other basins with the Site to determine TSS and concentration correlation, how likely maximum values occur simultaneously, or whether the data collected is in fact the maximum values that are likely to occur at the Site. Other studies have shown that there is no correlation between TSS and concentration. For the purposes of this analysis, it would be best to look at central tendency and worst case scenarios. Further, each sediment trap is a central tendency for that stormwater basin; thus, it would be appropriate to use the central tendency of TSS data from that basin for the analysis (i.e., take averages of TSS for each basin and then run statistics on the resulting values for land use loading calculations). It is appropriate to discuss the uncertainty in the range of estimates to ensure that these values are used appropriately in the Hybrid Model.
7.0, p.44 pp.1	Editorial	…comparison of stormwater ***solids*** loading concentrations…
7.1, p.44	Editorial/Technical	This section is acceptable for discussion of stormwater loads, but future analyses need additional section for discussion of stormwater solids loads. There should be a comparison of stormwater solids load calculated from whole water data, stormwater solids load calculated from sediment trap data with comparable mixed use basin solids loads.
7.1, p.44	Technical	In the future, this comparison should be conducted for range of data points (e.g., minimum, average and maximum) to have enough information to determine if the land use extrapolation method is within the realm of loads calculated for mixed-use basins.
7.2, p.45	Technical	In the future, do not conduct the detailed analysis in this section.

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Document Section	Editorial/Technical Comment	EPA Comment
Table 3-1	Editorial	In the future, present two tables; one for whole water and another for solids since the analytes measured for each media were not the same due to sample size.
Table 3-2 footnote 3	Editorial	…the fact that the bridge was recently ***repaved and repaired***.

Table X. Initial List of Chemicals and Unique Sites[1]

Outfall #	**Facility/Location**	**Chemicals**
WR-22	OSM	PCBs, PAHs, metals
WR-123	Schnitzer International Slip	PCBs, phthalates, metals
WR-384	Schnitzer - Riverside	Metals, PCBs
WR-107	GASCO	PAHs
WR-96	Arkema	Pesticides
WR-14	Chevron - Transportation	PAHs
WR-161	Portland Shipyard	PAHs, phthalates, metals, PCBs
WR-4	Sulzer Pump	PAHs, metals, PCBs
WR-145	Gunderson	PCBs, PAHs, phthalates, metals
WR-147/148	Gunderson (former Schnitzer)	PCBs, phthalates, metals, PAHs
	GE	PCBs
WR-183/Basin R	Terminal 4 – Slip 1	PAHs, TOC
WR-181/Basin Q	Terminal 4 – Slip 1	Metals, PAHs, TOC
WR-177/Basin M	Terminal 4 – Slip 1	Metals, PAHs
WR-169/Basin D	Terminal 4	Metals, PAHs
WR-20/Basin L	Terminal 4 – Wheeler Bay	PAHs
OF-22B	City – Doane Lake Industrial Area	Pesticides, metals
St. John's Bridge	Highway 30	PCBs, others (bridge repaving activity)

Note 1: The chemicals listed for each site in this table represents those chemicals that were initially thought to be unique chemicals for the site (i.e., the data set will fall outside the range of the heavy industrial land use), but will be evaluated in the stormwater loading process to determine if they are appropriately classified (i.e., unique vs. non-unique). The draft RI Report will identify the final list of sites and chemicals determined to be Unique.

ATTACHMENT 1

TECHNICAL MEMORANDUM
DRAFT

TO: Eric Blischke
USEPA

FROM: Rick W. Chappell, Ph.D.
Environmental Science Solutions LLC
Camp Dresser & McKee Inc.

DATE: October 29, 2008

SUBJECT: Portland Harbor, Stormwater Concentration Estimation
Recommended Approach

After review of the various approaches for calculating weighted statistics for stormwater concentration data, this technical memorandum (TM) provides a recommended approach based on stratified random sampling (Gilbert, 1987; Manly, 2001) and handling of left-censored (nondetect) data (Helsel, 2005). Refer to the "Chappell" sheet in the attached file: *GilbertStormwaterCalc.xls* for an example calculation.

Step 1 – Calculate Individual Basin Statistics

Individual sample statistics should be calculated for each individual basin, e.g., for the h^{th} basin, calculate the mean and estimated variance of the mean:

$$\overline{X}_h = \frac{\sum_{i=1}^{n_h} X_i}{n_h} \qquad (1)$$

$$\hat{V}ar(\overline{X}_h) = \frac{s_h^2}{n_h} \qquad (2)$$

In the above equations, note that n_h is the sample size of an individual basin, and that the sample means (Equation 1) and sample variances (s^2 in Equation 2) for an individual basin should be calculated using the approach recommended by Helsel (2005) which is summarized in Figure 1. It is anticipated that since n_h will likely be <50, either the Kaplan-Meier (KM) method (if percent censoring is less than 50) or the Robust ROS method (if between 50 and 80) will always be used. The KM method is nonparametric, so it will not be necessary to worry about the shape of the distribution in this case. The Robust ROS method is parametric, so the data should first be tested for normality or log-normality before applying this method. Either of these methods may be implemented in several ways:

- Using the commercial statistics program MINITAB with the public domain macros developed by Helsel and available from www.practicalstats.com.
- Using the public domain program R ("GNU S") with Helsel's statistical analysis package.
- Using the public domain program ProUCL and selecting the appropriate options and methods.

In addition, a program developed within Excel using VBA macros may be implemented to automate the calculations.

Note that in the case of no nondetects, the KM method will give the same values as would be calculated directly, i.e., one may use the KM method or just calculate the statistics directly, with the same results. Typically, the Robust ROS method is implemented assuming the data were derived from a log-normally distributed population; however, a more rigorous approach would be to select the distribution (normal or log-normal) following examination of graphical displays (e.g., probability plots) and/or more formal tests of normality (Shapiro-Wilk or Anderson-Darling methods). Note, however, that only the detects (not the nondetects) can be displayed graphically and/or tested for normality, which may make the assessment of normality difficult in cases with 50-80% nondetects where the Robust ROS method is to be used (this is why the usual "default" practice is to assume log-normality). In practice, if it proves impossible to assess normality due to small numbers of detects, then the approach should default to the KM method regardless of the percentage of nondetects, as long as they are not above about 80%. (This is not indicated in Figure 1. Helsel recommended the approach summarized in Figure 1, whereby the KM method was restricted to cases with less than 50% nondetects, because of the inability of the KM method to estimate the median if greater than 50% nondetects. However, assuming we are not interested in the median, this restriction is no longer applicable, and therefore the KM method can be used for up to 80% nondetects.)

Step 2 – Calculate Overall Statistics using Weighting Factors

Overall statistics (for the k basins) should be calculated by summing the individual basin statistics after weighting them according to their relative "sizes" (discussed further below):

$$\overline{X} = \sum_{h=1}^{k} W_h \overline{X}_h \tag{3}$$

$$\hat{V}ar(\overline{X}) = \sum_{h=1}^{k} W_h^2 \hat{V}ar(\overline{X}_h) \tag{4}$$

In the above equations, the weighting factors (W_h) should be appropriate size ratios developed based on project-specific and scientific reasoning. It is anticipated that a standardized flow volume will be used, whereby the weighting factor for an individual basin will be the flow for that basin divided by the total flow for all basins included in the calculation. Note, however, that the appropriateness of flow weighting has not been evaluated as part of this TM, but rather only a recommended approach is provided under the assumption that the flow weighting approach is valid. The basic idea behind "size" weighting in general is that basins with larger weighting factors would (and perhaps should) exhibit a larger influence on the overall statistics. If the observations (samples) within a basin are more similar to each other than they are to the observations in general (across the basins), then the estimate of the overall mean will have a smaller variance, and therefore a smaller standard error (as discussed further in Step 3). A smaller overall standard error will also result if the variability is lower within a relatively more highly weighted basin. In either case, upper confidence limits (see Step 3) will be lower.

Step 3 – Calculate Intervals for Overall Statistics

Confidence, tolerance, and prediction intervals may be calculated using the overall statistics obtained via Equations 3 and 4. It is anticipated that the desired interval will be a 95% one-sided upper confidence interval, or upper confidence limit (*UCL95*) of the mean:

$$UCL95 = \overline{X} + (t_{0.05,n-1})\sqrt{\hat{V}ar(\overline{X})} \quad (5)$$

Note that in the above equation, the square root of the estimated variance calculated via Equation 4 is the estimated standard error of the mean, and that n is the overall sample size (across all basins). Also note that by definition Equation 5 invokes the central limits theorem (CLT), i.e., the sampling distribution of the mean will approach a normal distribution. Equation 5 can be easily calculated in Excel without the need for other software. Invoking the CLT is reasonable when the sample size (n) is sufficiently large. How large n must be will depend on the skewness of the distributions (within the individual basins) which may prove difficult to assess. If the distributions are highly skewed, the rule-of-thumb is that n should be greater than about 50, which, however, is unlikely to be the case. Hence, a better approach to calculating the *UCL95* would be to conduct a bootstrap simulation, using either the MINITAB macro or R package provided by Helsel, or the implementation of the bootstrap provided in the ProUCL program.

Finally, it may be useful to state precisely what a *UCL95* actually implies. For the example in the attached workbook, a mean of 2,284 and *UCL95* of 2,996 were calculated. The calculations were made based on the sample sizes for the individual basins provided (assumed randomly collected and normally distributed). If the sampling were to be repeated exactly (i.e., another set of n samples collected again) then another mean would be calculated, i.e., another realization, which would likely be different from the first realization. If this process were to be repeated many times, then the set of calculated realizations of the mean would be normally distributed and it could be stated with 95% confidence that the true population mean (μ) is less than 2,996, or, on average 95% of the mean realizations (95 out of 100) would be less than 2,996.

References

Gilbert, R.O., 1987, Statistical Methods for Environmental Pollution Monitoring, Van Nostrand Reinhold.

Helsel, D.R., 2005, Nondetects and Data Analysis, Statistics for Censored Environmental Data, Wiley.

Manly, B.F., 2001, Statistics for Environmental Science and Management, Chapman & Hall/CRC.

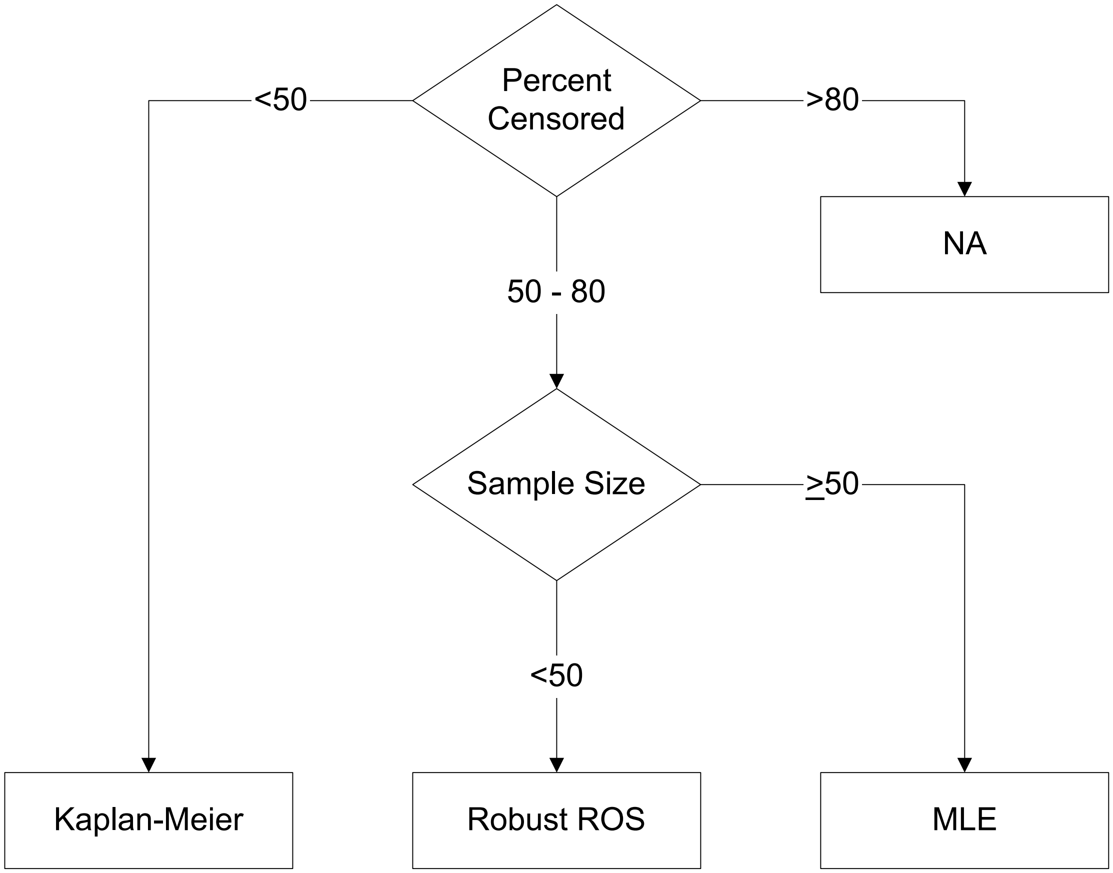

Figure 1. Recommended approach for calculating sample statistics.

Attachment A-1
Weighted Flow Example

Strata (Basin)	Nh (Flow)	Wh (Flow Fraction)	nh (number of samples)	Measure (conc.)	Xh (mean)	S2h (Variance)	WhXh (Flow-weighted average)	Wh2S2h (Weighted variance)
A	9,800	0.036	5	126	128	2,218	5	2.9
A				70				
A				306				
A				103				
A				35				
B	30,380	0.112	5	6,080	4,354	2,629,706	486	32793.3
B				9,780				
B				3,410				
B				1,170				
B				1,330				
C	90,060	0.331	4	628	1,148	105,592	380	11571.7
C				1,720				
C				1,700				
C				544				
D	41,810	0.154	3	5,800	6,077	4,021,211	934	94977.3
D				9,680				
D				2,750				
E	100,000	0.368	3	2,250	1,304	225,107	479	30415.2
E				770				
E				891				
Sum	272,050	1	20				2,284	169,760

Conf. Level	0.95
Mean	2,284
z	1.645
t	1.729
UCL(z)	2,962
UCL(t)	2,996

ATTACHMENT 2

Confidence Intervals (Cont.)

– Normal 2-sided for Quantile (β)

$$\left(\bar{x} + k_{2,\alpha,\beta,n} s < \beta < \bar{x} + k_{2,1-\alpha,\beta,n} s\right) = 1 - \alpha$$

– Normal 1-sided for Quantile (β)

$$\left(\bar{x} + k_{1,\alpha,\beta,n} s < \beta\right) = 1 - \alpha \qquad \left(\beta < \bar{x} + k_{1,1-\alpha,\beta,n} s\right) = 1 - \alpha$$

Normal 2-sided Confidence Intervals for Quantiles

$$k_{2,\alpha,\beta,n} = r\sqrt{\frac{n-1}{\chi^2_{1-\alpha,\nu}}} \qquad k_{2,1-\alpha,\beta,n} = r\sqrt{\frac{n-1}{\chi^2_{\alpha,\nu}}}$$

$$\beta = \int_{1/\sqrt{n}-r}^{1/\sqrt{n}+r} \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}x^2}\, dx = F(1/\sqrt{n}+r) - F(1/\sqrt{n}-r)$$

Given desired β must first solve bottom equation for *r* (requires iteration) and then given *r* and a desired α must solve top equations to obtain the k_2 coefficients.

Normal 1-sided Confidence Intervals for Quantiles

$$k_{1,1-\alpha,\beta,n} = \frac{t'_{1-\alpha,n-1,z_\beta\sqrt{n}}}{\sqrt{n}}$$

$$k_{1,\alpha,\beta,n} = \frac{t'_{\alpha,n-1,z_\beta\sqrt{n}}}{\sqrt{n}}$$

Noncentral *t* Distribution

Illustration – Normal 2-sided Confidence Interval for 0.95 Quantile

Data
51
72
71
49
63
33
48
51
34
61

$$\left[53.3+(1.4982)(13.6)<\beta<53.3+(3.3794)(13.6)\right]=1-0.05$$

$$\left(73.6<\beta<99.2\right)=0.95$$

Thus, given that the data represent a random sample from a normal population, we can state that with 95% confidence the interval 73.6 – 99.2 contains the 95th Percentile of the population (on average, 95 out of 100 such random interval realizations would contain β).

ATTACHMENT 3

Stochastic modeling of stormwater and receiving stream concentrations

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ABSTRACT: A stochastic approach was developed and applied to the Butte, Montana hillside abandoned mining site for modeling stormwater runoff and subsequent receiving stream loadings. This approach enabled capture and quantification of the uncertainty associated with stormwater quality data and allowed the prediction of copper and zinc concentrations caused by runoff from the Butte hillside during storm events. Runoff flows were generated in a spreadsheet model using the rational method and stormwater concentrations were input as probability distribution functions (PDFs). Correlations between sampling sites were also incorporated into the model. The PDFs were combined with runoff hydrographs and stochastically modeled using Monte Carlo simulation. Stream loadings predicted by the model PDFs were combined with ambient stream flow and quality in a mass balance to generate expected stream concentrations in the form of cumulative distributions functions (CDFs). The final stream concentration CDFs were used to evaluate the probabilities of exceeding instream standards at various locations during a specific storm event.

1 INTRODUCTION

The Silver Bow Creek / Butte Area NPL site encompasses the majority of the historic Butte Mining district where metals mining has been conducted on a large scale for over a century. The site consists of former mining, milling, smelting, and related facilities and associated waste rock dumps, tailings impoundments, mill and smelter wastes, and contaminated soils within and surrounding the populated areas of Butte and Walkerville, Montana (CDM 1990). Surface water in Silver Bow Creek (SBC), the receiving stream at the site, is impaired as a result of impacts from mining-related waste materials and from urban discharge (DEQ 1998). Elevated concentrations of metals leached and eroded from mining-impacted soils and waste materials, as well as channel alterations and industrial and municipal point source discharges, have impaired water quality within the creek such that populations of fish and other aquatic species are very low to non-existent.

A preliminary remedial action objective for SBC is to return the creek to its beneficial uses, which includes providing protection of aquatic communities from direct contact with and/or ingestion of site-related contaminants. SBC is greatly impacted by stormwater runoff from the Butte Hillside adjacent to the upstream end of the creek. Therefore, to meet remedial goals, episodic stormwater runoff events will need to be controlled so that acute in-stream water quality exceedances within SBC are prevented to the greatest extent practicable.

This paper describes a modeling approach implemented to predict acute instream copper (Cu) and zinc (Zn) concentrations resulting from stormwater runoff under specified storm conditions and to evaluate the effectiveness of existing and planned Best Management Practices (BMPs). Copper and Zn were selected for modeling because aquatic organisms are sensitive to elevated concentrations of these two metals; however, the modeling approach is applicable for any contaminant in stormwater. The approach involved using stochastic methods to incorporate the uncertainty associated with measured stormwater quality data. Specific objectives of this investigation (CDM 2000) were to (1) model instream concentrations in SBC for three 24-hour design storms (2, 5, and 10 year), (2) compare predicted concentrations with and without existing BMP controls, (3) evaluate and prioritize target areas for future BMPs, and (4) identify and evaluate significant modeling data gaps to guide subsequent sampling plans.

2 SITE BACKGROUND

The Silver Bow Creek / Butte Area NPL site encompasses approximately 85 square miles (mi^2). The area targeted in this study (Figure 1), which covers an area of approximately 5 mi^2, is a sub-region of this larger site and encompasses the town of Walkerville, the part of Butte just north of the initial reach of SBC.

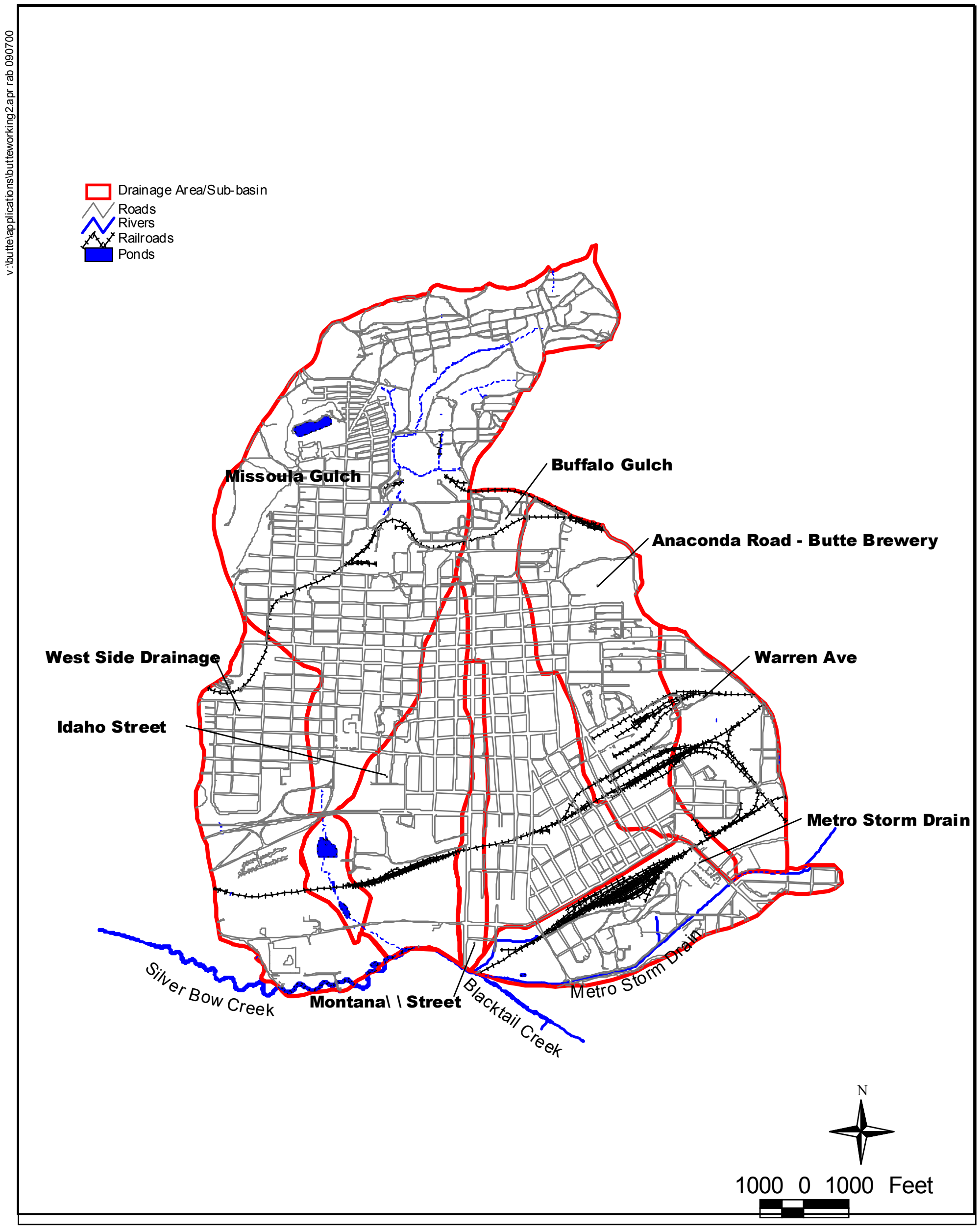

Figure 1. Butte hillside location map.

SBC is a small mountain stream with low to moderate discharge during normal flow conditions (18 - 23 cubic feet per second [cfs]) relative to the potential volume of stormwater runoff (e.g., 477 cfs for the 10-year, 24-hour peak flow [ESA 1998]). The effective drainage area of SBC is approximately 103 mi^2. SBC originates at the confluence of the Butte Metro Storm Drain and Blacktail Creek. The Metro Storm Drain is an open channel that was constructed in the early 1930s. The upper portion of this drain is dry except during storm runoff or snowmelt events while the lower portion receives flow via ground water discharge and, during normal flow conditions, contributes between 0.3 and 0.5 cfs to SBC. The primary source of flow in SBC is inflow from Blacktail Creek, which originates in the Highland Mountains and has a drainage basin area of approximately 95 mi^2. Blacktail Creek normally contributes 11 to 15 cfs to SBC. The Metro Storm Drain and SBC receive flow from several sub-drainage basins on the Butte Hillside during stormwater runoff and snowmelt, including Warren Avenue (Warren), Anaconda Road/Butte Brewery (Anaconda), Buffalo Gulch (Buffalo), Missoula Gulch (Missoula), Montana Street (Montana), Idaho Street (Idaho), and West Side (West Side).

In addition to the perennial stream flow and stormwater runoff, SBC receives regulated discharge from the Butte Metro Waste Water Treatment Plant (WWTP) of between 5 and 9 cfs. Additionally, Lower Missoula Gulch intercepts shallow groundwater and maintains a baseflow discharge to SBC of 0.1 to 0.3 cfs (ESA 1999). BMPs have been implemented in the past five years in the area and include a combination of engineered controls (catch basins, channels, culverts, etc.) and reclamation practices (grading, soil covers, erosion control fabric, etc.).

3 STORMWATER RUNOFF MODELING

Stormwater runoff modeling was performed to predict runoff from the Butte Hillside sub-basins discharging to SBC under varying storm conditions. The model was based on the HEC-STORM model algorithm. The model uses the rational method to predict runoff at hourly timesteps from a given watershed for a given storm event, $Q = CIA$, where Q = runoff flow (cfs), C = runoff coefficient (an empirical coefficient that captures the ratio of expected runoff to precipitation and is dependent on watershed characteristics), I = rainfall intensity (in/hour), and A = drainage area (acres). The model also tracks available depression storage (ponding volume from small depressions throughout the drainage area) and subtracts out a corresponding abstraction (as the depression storage fills up) at each timestep. Use of this model to predict runoff hydrographs is generally valid only for small urban watersheds where the time of concentration (the time it takes runoff from the uppermost portion of the watershed to reach the discharge point) is small.

Runoff coefficients (C) and depression storage (inches) for each sub-basin were calculated from land-use characteristics and assumed percent imperviousness values for the various land-use categories. Sub-basins were delineated for both pre-BMP (prior to the start of BMP implementation about five years ago) and post-BMP (existing basin) scenarios to be modeled.

Twenty-four hour design storms at 2, 5, and 10 year recurrence intervals were selected for modeling. The storm hydrographs were calculated using a Type 2 distribution of precipitation totals taken from the Precipitation Intensity Frequency Atlas for Montana (NOAA 1988), as shown in Figure 2. These storms were input to the model at hourly timesteps and show the greatest intensity in the first hour and decrease in intensity in subsequent hours.

The major BMPs were incorporated in the model (for the post-BMP scenarios) through diversions in the runoff flow, reductions in drainage areas, land-use alterations, and explicit modeling of the detention pond system constructed in the Missoula Gulch sub-basin. The model simulates runoff inflow captured by the ponds, and overflow and controlled outflow from each pond. The overflows and controlled outflows add to the uncaptured basin runoff and discharge to SBC.

4 STATISTICAL ANALYSES OF STORMWATER QUALITY DATA

Statistical analyses of Cu and Zn concentrations (dissolved and total) were conducted to determine the input variables for both pre and post-BMP models. Statistical results indicated that Cu and Zn concentrations for the model inputs were lognormally distributed. Therefore, natural log transformed data were used to generate geometric means and geometric standard deviations for use in the stochastic modeling. For sub-basins with insufficient data for statistical analysis, stochastic input parameters were estimated from other sub-basins with similar land-use characteristics.

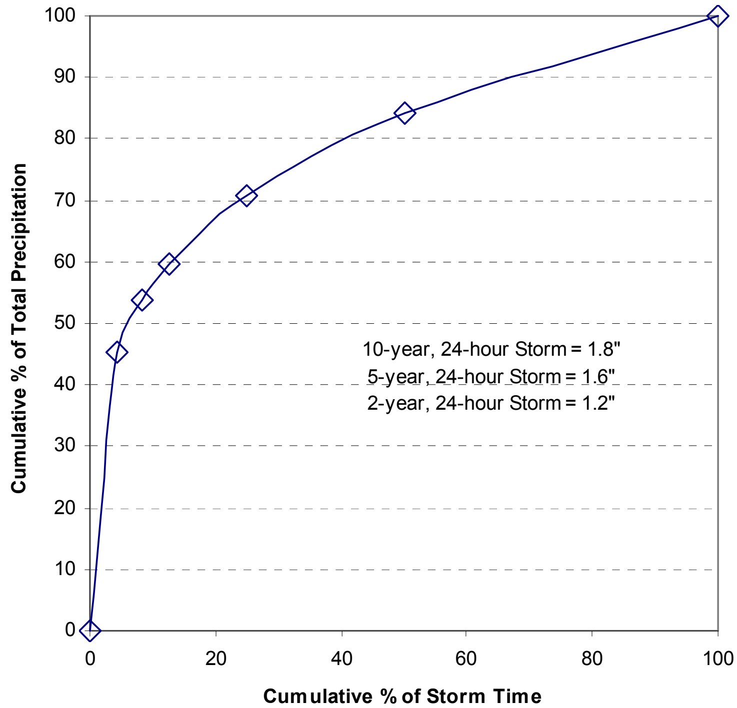

Figure 2. Type 2 design storm.

Statistical analyses were also conducted to identify data correlations between the various sub-basins. This analysis was limited to stormwater data pairs, i.e., samples collected on the same day from two or more sub-basins. The resulting sets of correlation coefficients were averaged to obtain a single correlation coefficient for use in the model. The use of correlations in this manner is based on the assumption that concentrations among the sub-basins for a particular storm event will be related. For example, if concentrations at a particular sub-basin are relatively high, concentrations at all other sub-basins will also be relatively high.

5 STOCHASTIC PREDICTIONS OF INSTREAM CONCENTRATIONS

Due to the uncertainty associated with measured stormwater concentrations, with respect to both the large standard deviations and the timing of sampling and storm events, a stochastic approach was utilized to simulate runoff loadings and resulting acute SBC concentrations. The @Risk addin program to Microsoft Excel was used in conjunction with the runoff model and the water quality statistical analyses. @Risk is a stochastic modeling tool that incorporates and quantifies the uncertainty of specified input parameters by using Monte Carlo simulations to run a given model for a large number of iterations while randomly sampling input probability distributions for each stochastic parameter at each iteration. The resulting output variables are presented in the form of CDFs of expected values.

The SBC model was set up as a stream mixing spreadsheet where 24-hour stormwater hydrographs are combined with assumed upstream and groundwater flow and concentration conditions to calculate expected downstream concentrations. The model assumes instant and complete mixing in the stream. For each simulated storm event (2, 5, and 10 year 24-hour storms) runoff hydrographs were determined for each sub-basin externally using the runoff model. These hydrographs were then used as the flow inputs to the mixing model. The PDFs for stormwater and groundwater concentrations at each sub-basin were input as stochastic variables to the instream model. Correlation coefficients between each of the sub-basin PDFs were also input.

During a given simulation, the model, at each timestep, randomly sampled the sub-basin PDFs (incorporating the appropriate correlations) to generate stormwater/groundwater concentrations. These concentrations were combined with the runoff flows and mixed with ambient stream conditions to generate instream concentrations throughout the reach of interest. This process was repeated thousands of times within a given simulation. The model output was in the form of CDFs that predict 24-hour average instream concentration exceedance probabilities at selected points along SBC. Figure 3 summarizes the modeling process.

Separate simulations were performed for each of the contaminants of concern, for each of the three storm events (2, 5, and 10 year), and for each of the two site characteristic scenarios (pre and post BMP conditions).

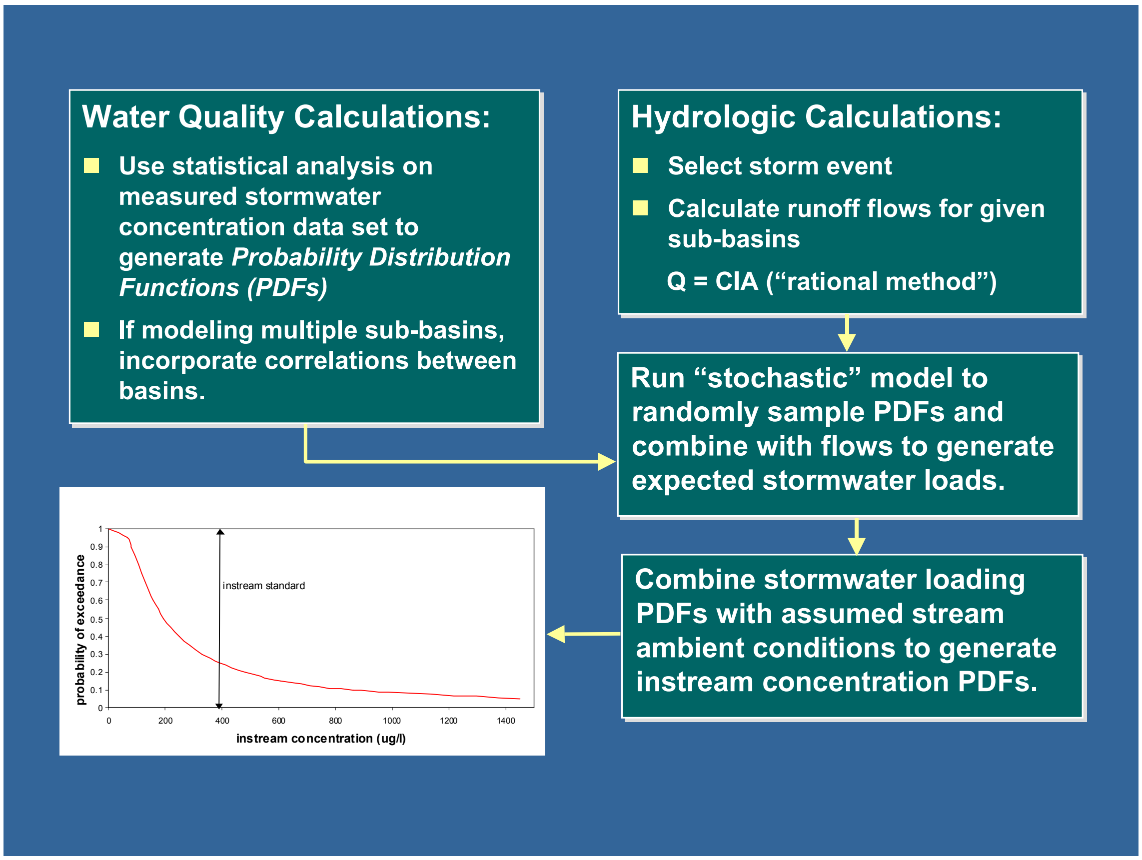

Figure 3. Stochastic modeling overview.

6 RESULTS AND DISCUSSION

6.1 *Predicted Instream CDFs*

Figure 4 shows an example CDF generated by the stochastic model, in this case for instream total Zn concentrations at the furthest point downstream in the SBC reach of interest. Included on Figure 4 are CDFs for pre and post BMP model results under each of the three simulated storm events. As an example of how to interpret the CDFs, an exceedance probability of 0.4 represents a 40% chance of exceeding the corresponding concentration as a 24-hour average for the given storm event. Histogram distributions of measured total Zn concentrations are provided for comparison with the modeled CDFs.

The results shown in Figure 4 indicate that significant improvements in predicted total Zn concentrations have likely occurred following BMP implementation, e.g., about a 35% reduction in the 20% exceedance concentration. The results also indicate that differences in total Zn concentrations due to varying magnitudes of storm events are very small. Furthermore, while measured total Zn concentrations fall within the CDF ranges predicted by the model, they tend to cluster near the lower concentration end, indicating the influence of sample collection during ambient rather than storm event periods. Similar results were obtained for dissolved Zn and total and dissolved Cu.

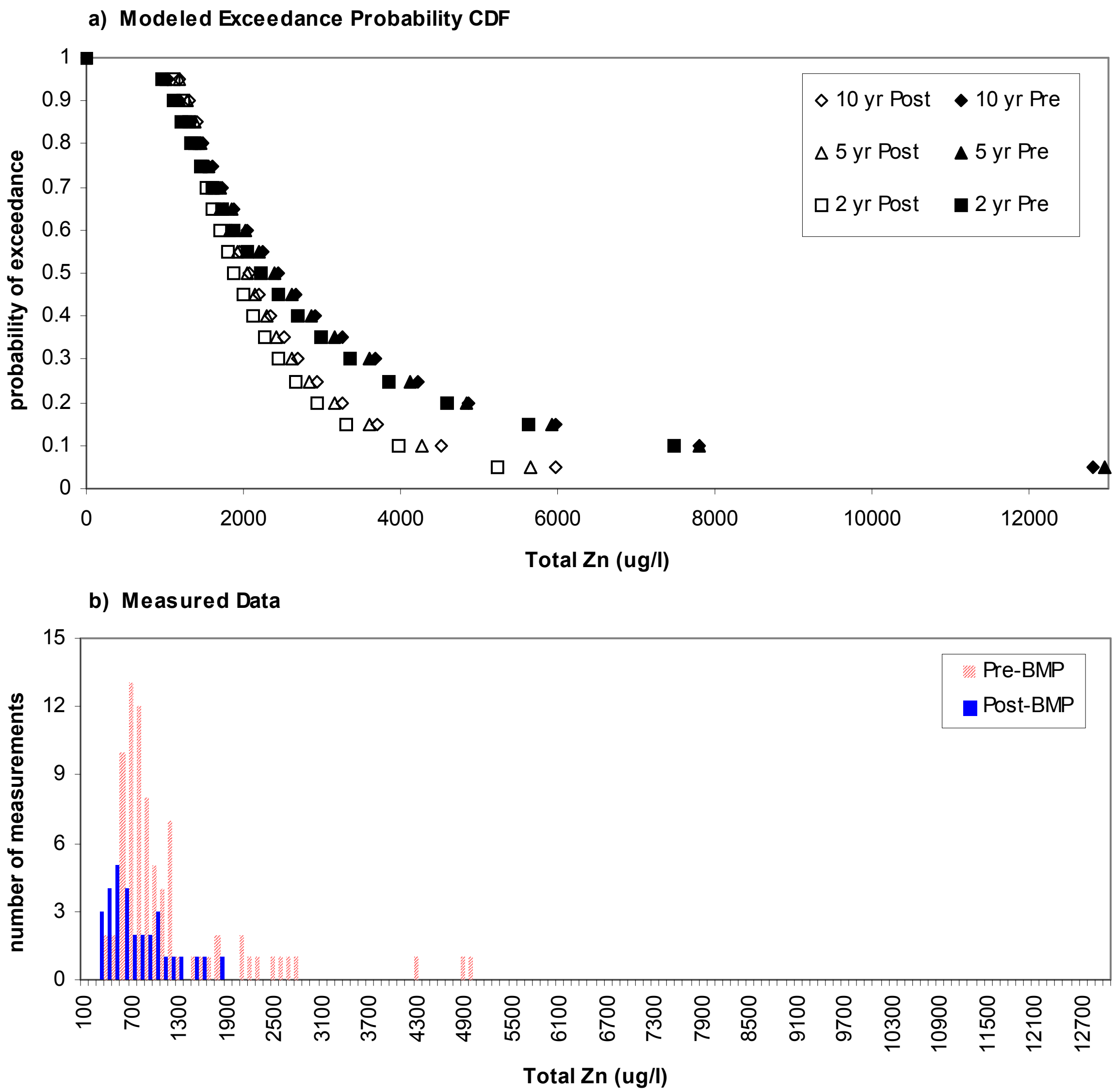

Figure 4. Modeled and measured results for Silver Bow Creek.

6.2 *Model Sensitivity Analyses*

To further evaluate model uncertainty, three key non-stochastic model parameters were investigated in terms of model sensitivity: groundwater inflow, Blacktail Creek flow (upstream steady flow), and the correlation coefficient matrix. The uncertainties associated with these model inputs were not captured in the stochastic approach. For each of these parameters, the model input values were varied over a reasonable range and the resulting instream CDFs were compared to the original modeled results. Groundwater inflows, which were included as steady flows in the instream mixing model at both the Missoula Gulch outfall and as a portion of the Metro Storm Drain contribution, and the Blacktail Creek upstream flows were varied ± 100% during the sensitivity analysis. The correlation coefficient matrix was varied from 0.0 to 1.0. Total copper at the most downstream location on SBC was predicted for the 10-year storm, post-BMP scenario.

The results of the sensitivity analyses indicate very little model sensitivity to groundwater flow (Figure 5) and a slightly higher sensitivity to the correlation coefficient matrix (Figure 6), with exceedance concentration differences reaching as high as +19% but generally below ±15%. The model was most sensitive to Blacktail Creek flow variations (Figure 7), with modeled concentration differences of approximately ± 20% throughout most of the distribution. The sensitivity to Blacktail Creek is expected as the Blacktail Creek headwater flow is a primary dilution factor in the model. The flow value used in the stochastic modeling represents a conservative assumption of baseflow conditions in Blacktail Creek. Increased upstream flow in Blacktail Creek due to storm conditions was not incorporated into the scenarios modeled here but could easily be altered for future uses of the model.

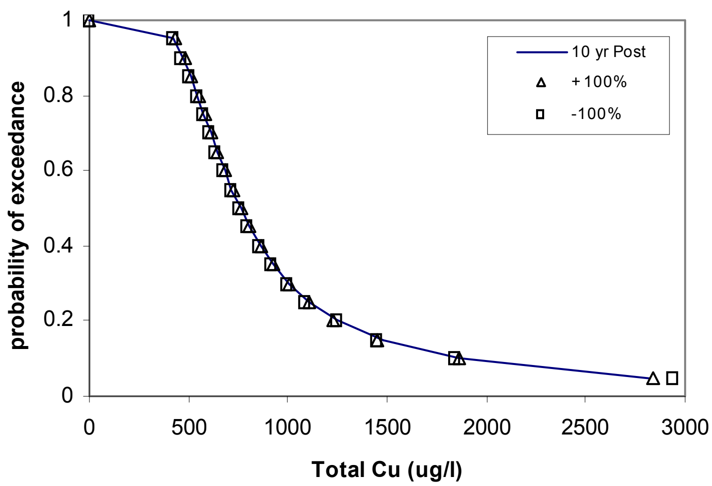

Figure 5. Groundwater flow sensitivity for 10-year, 24-hour storm.

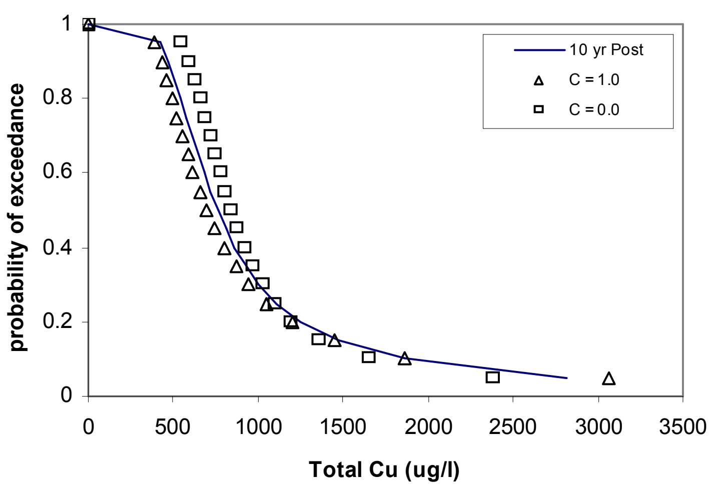

Figure 6. Correlation Coefficient sensitivity for 10-year, 24-hour storm.

6.3 *Future BMP Implementation*

To help guide future BMP implementation, the impacts of individual sub-basin loading removals on instream concentrations were evaluated. The post-BMP model was modified by removing loads one sub-basin at a time and comparing the new predicted 50% exceedance concentration with the original model concentration for the 2-year storm. Groundwater and the wastewater treatment plant effluent loads were also included in this analysis. These types of simulations only allow for the comparison of relative effects of *isolated* loading removal rather than of any combined loading removal.

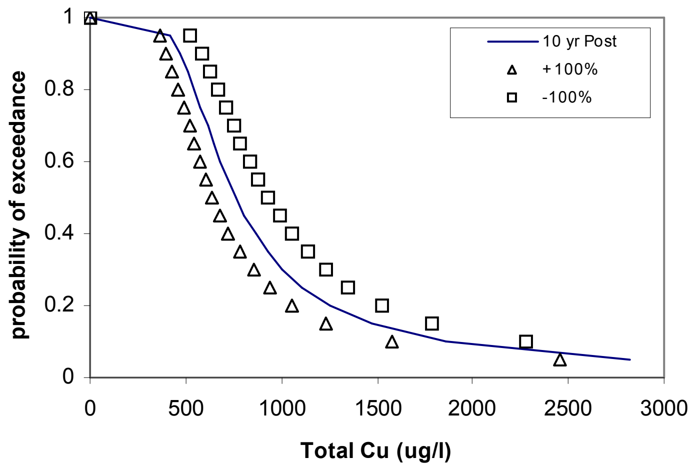

Figure 7. Blacktail Creek flow sensitivity for 10-year, 24-hour storm.

Concentrations at the downstream-most station on SBC were analyzed. Figure 8 represents an example of the results for dissolved Cu. As shown, individual removals of the Warren, Anaconda, and Missoula sub-basins (both surface water and groundwater for Missoula) resulted in percent dissolved Cu reductions ranging between about 7 and 12%, indicating that these sub-basins would be good areas to focus future BMP efforts. Note that removal of the WWTP discharge results in a negative percent reduction (or increase) because it represents a dilution component for dissolved Cu.

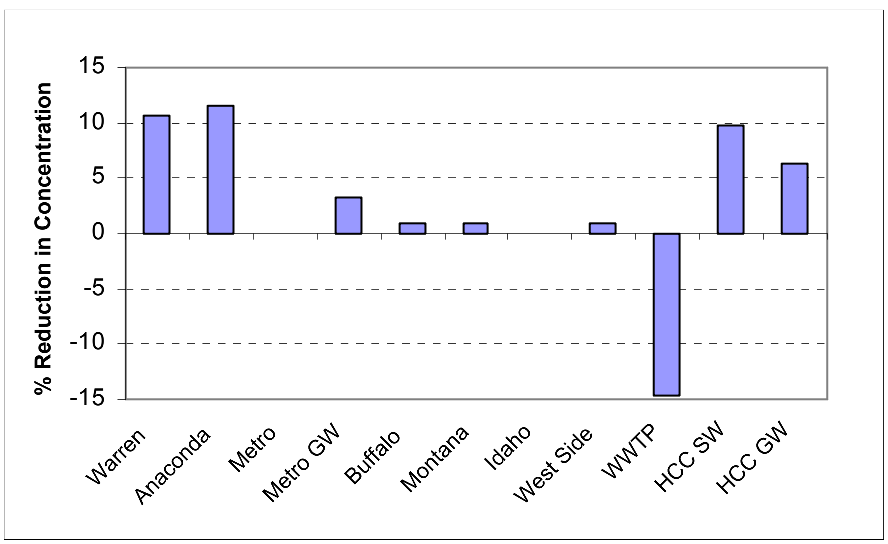

Figure 8. Effects of isolated sub-basin loading capture on Silver Bow Creek dissolved Cu concentration. HCC SW is Missoula surface water and HCC GW is Missoula groundwater.

6.4 *Model Limitations*

The ability of the stochastic model to accurately predict SBC water quality depends on the quality of the data input variables. There are several limitations of the current model that warrant further characterization. First, the stochastic approach relies on measured data and model accuracy is limited by the quality and quantity of the data. For this case study, data gaps were filled by assuming similar concentration distributions between sub-basins with similar land-use characteristics. Second, a constant correlation coefficient was used for all sub-basins despite the fact that the value most likely varies between sub-basin pairs. Third, the current model does not include a component for storm-induced re-suspension of contaminated sediments contained in SBC. Finally, the impacts of reclamation BMPs in certain sub-basins were not incorporated into the current model. In particular, only loading reductions due to flow capture and diversions were incorporated in the current model, whereas BMPs that may have reduced storm water concentrations were not. With adequate post-BMP concentration data, reclamation BMPs could easily be included.

7 SUMMARY AND CONCLUSIONS

The stochastic approach to modeling stormwater and receiving stream concentrations at the Butte hillside proved useful for characterizing the uncertainty associated with stormwater quality data. This approach enabled prediction of SBC water quality resulting from various storm events, evaluation of critical data needs, and characterization of the impacts of BMPs implemented at the site. Most importantly, the model provides a tool for guiding subsequent data collection, so that future BMP activities can be focused to provide maximum benefit. This approach is considered extendable to similar mining waste sites where stormwater runoff is impacting stream water quality.

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